EFFECT OF ABRASIVE TOOLS ON SURFACE FINISHING WHEN GRINDING MILD STEEL

ABD FAIZ BIN MUHAMMAD

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

Signature:

Name of Supervisor: MR. KUMARAN A/L KADIRGAMA

Position: LECTURER

Date: 6 DECEMBER 2010

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature:

Name: ABD FAIZ BIN MUHAMMAD

ID Number: ME 07014

Date: 6 DECEMBER 2010

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ABSTRACT

The main purpose of this study is to study the effects of abrasive tools on mild steel surface by using three parameters (depth of cut, table speed, and mode of dressing). This study was conducted by using surface grinding machine. Taguchi method was employed as an analysis tool for this study. Total series of experiments performed was 9 set for each grinding wheels (Silicon Carbide and Aluminium Oxide). Statistical software was used to predict the surface roughness. To validate the prediction result, experimental values compared. Result showed that lower depth of cut, lower table speed and lower mode of dressing produced better surface finish. For the abrasive tools used, the Aluminium Oxide wheel produced lower value of surface roughness compared with the Silicon Carbide wheel. The predicted result showed that depth of cut, table speed and dressing mode are significant parameter in influencing of surface roughness.

ABSTRAK

Tujuan utama kajian ini adalah untuk mempelajari pengaruh alat ‘abrasive’ terhadap permukaan mild steel dengan menggunakan tiga parameter (kedalaman potongan, kelajuan meja, dan cara ‘dressing’). Kajian ini dilakukan dengan menggunakan ‘surface grinding machine’. Kaedah Taguchi digunakan sebagai alat analisis untuk kajian ini. Jumlah siri percubaan yang dijalankan adalah 9 siri untuk setiap jenis ‘grinding wheels’ (Silicon Carbide and Aluminium Oxide). Perisian statistik digunakan untuk meramal nilai kekasaran permukaan. Untuk mengesahkan hasil ramalan, keputusan daripada eksperimental dibandingkan. Dari keputusan yang diperoleh, dapat disimpulkan bahawa kedalaman pemotongan yang rendah, kelajuan meja rendah, dan ‘dressing mode’ yang rendah menghasilkan permukaan akhir yang lebih baik. Untuk alat ‘abrasive’ yang digunakan, roda ‘Aluminium Okside’ menghasilkan nilai kekasaran permukaan yang lebih rendah berbanding dengan roda ‘Silicon Carbide’. Hasil ramalan menunjukkan bahawa kedalaman pemotongan, kelajuan meja dan cara ‘dressing’ adalah parameter yang signifikan dalam mempengaruhi kekasaran permukaan bahan.

TABLE OF CONTENTS

SUPERVISOR DECLARATION		ii
STUDENT DECLARATION		iii
ACKNOWLEDGEMENT		iv
ABSTRACT		v
ABSTRAK		vi
TABLE OF CONTENT		vii
LIST OF TABLE		x
LIST OF FIGURE		xi
CHAPTER 1: INTRODUCTION		
1.1	Project Background	1
1.2	Problem Statement	2
1.3	Project Objectives	2
1.4	Scope of Project	3
1.5	Summary	3
CHAPTER 2: LITERATURE REVIEW		
2.1	Introduction	4
2.2	Surface Grinding Machine	4
	2.2.1 Process of Surface Grinding	5
	2.2.2 Equipment	5
	2.2.3 Type of Surface Grinders	6
	2.2.4 Grinding Wheels for Surface Grinders	7
	2.2.5 Lubrication	7
	2.2.6 Grinding Machine Safety	7
2.3	Wheel Structure	8
	2.3.1 Grain Size	9
	2.3.2 Bonds	10
2.4	Parameters that affecting Surface Finish in Surface Grinding Operation	10
	2.4.1 Grinding Forces	10

2.4.2 Dressing Mode 12

2.4.3 Cutting Fluid 12

2.4.4 Depth of Cut 13

2.5 Interaction of The Abrasive Grains and The Workpiece Surface 14

2.5.1 Attack Angle of The Abrasive Grains 14

2.6 Dry Grinding 15

2.7 Surface Roughness 15

2.8 Parameters and Their Selection Strategies 16

2.9 Application of Taguchi Method 18

2.9.1 Selection of OA and Assignment of Factors 19

2.9.2 Evaluation of S/N Ratios 19

2.10 Response Surface Methodology 19

2.11 Perthometer S2 20

CHAPTER 3: METHODOLOGY

3.1 Introduction 22

3.2 Literature Study 22

3.3 Material Preparation 23

3.4 Selection of Parameters 23

3.5 Surface Grinding Process 24

3.6 Recording Data 25

3.7 Surface Roughness Test 27

3.8 Data Discussion 27

3.9 Wheel Type 28

3.9.1 Aluminium Oxide wheel 28

3.9.2 Silicon Carbide wheel 28

3.9.3 Grinding Wheel Specification 29

3.10 Procedure of Experiment 29

3.11 Dressing Process 30

3.12 Process to Measure the Surface Roughness 30

3.13 Summary 31

CHAPTER 4: RESULT AND DISCUSSION

4.1 Introduction 32
4.2 Experimental Result 32
4.2.1 Result of Chemical Composition Test of Mild Steel 32
4.3 Surface Roughness 34
4.3.1 Figure of Surface Roughness 35
4.3.2 Analysis of Surface Roughness Value in Response to Depth of Cut, Table Speed and Dressing Mode 37
4.4 Analysis of Control Factors 40
4.4.1 Signal to Noise Ratio 40
4.5 Prediction Result of Surface Roughness using Minitab 15 47
4.5.1 Response Surface Regresion (Silicon Carbide Wheel) 47
4.5.2 Response Surface Regresion (Aluminium Oxide Wheel) 50
4.5.3 Discussion of Response Surface Methodology Modelling Results 53
4.6 Comparison of Surface Textures 56

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Introduction 57
5.2 Conclusion 57
5.3 Recommendations 58

REFERENCES 59
APPENDIXES 62

LIST OF TABLE

Table No.	Title	Page
3.1	Silicon Carbide wheel	26
3.2	Aluminium Oxide wheel	26
4.1	Result from arc spectrometer tester	33
4.2 (a)	Surface roughness for Silicon carbide wheel	34
4.2 (b)	Surface roughness for Aluminium oxide wheel	35
4.3 (a)	Response table for S/N ratios (smaller is better) for Silicon carbide wheel	41
4.3 (b)	Response table for Means for Silicon carbide wheel	42
4.4 (a)	Response table for S/N ratios (smaller is better) for Aluminium oxide	43
4.4 (b)	Response table for Mean for Aluminium oxide	45
4.5	Estimated Regression Coefficients for surface roughness	47
4.6	Analysis of Variance for surface roughness	48
4.7	Unusual observations for Ra	48
4.8	Estimated linear regression equation	48
4.9	Predicted Response for New Design Points Using Model for surface roughness	49
4.10	Estimated Regression Coefficients for surface roughness	50
4.11	Analysis of Variance for surface roughness	50
4.12	Unusual observations for Ra	50
4.13	Estimated linear regression equation	51
4.14	Predicted Response for New Design Points Using Model for surface roughness	51

LIST OF FIGURES

Figure No.	Title	Page
2.1	Surface Grinder with electromagnetic chuck	5
2.2	Compositions of a grinding wheel	8
2.3	Illustration of wheels structure	9
2.4	Grinding force versus Depth of Cut Graph	11
2.5	Perthometer S2	21
3.1	Band saw machine	23
3.2	Milling machine	23
3.3	Surface Grinding Machine	24
3.4	Design Layout	25
3.5	Perthometer	27
4.0 (a)	Example of Ra values for Silicon Carbide wheel	36
4.0 (b)	Example of Ra values for Aluminium Oxide wheel	36
4.1	Graph of surface roughness VS depth of cut for different wheels	37
4.2	Graph of surface roughness VS mode of dressing for different wheels	38
4.3	Graph of surface roughness VS table speed for different wheels	39
4.4 (a)	Main effect plots for S/N ratio for surface Roughness (Ra) by using Silicon Carbide wheel	41
4.4 (b)	Main effect plots for Means for surface Roughness (Ra) by using Silicon Carbide wheel	43
4.5 (a)	Main effect plots for S/N ratio for surface Roughness (Ra) by using Aluminium Oxide wheel	44
4.5 (b)	Main effect plots for Means for surface Roughness (Ra) by using Silicon Carbide wheel	45
4.6 (a)	Interaction plot for S/N ratio for surface Roughness (Ra) by using Silicon Carbide Wheel	46
4.6 (b)	Interaction plot for S/N ratio for surface Roughness (Ra) by using Aluminium Oxide Wheel	46
4.7	Linear normal plot (Silicon carbide wheel)	53

4.8	Linear contour plot (Silicon carbide wheel)	53
4.9	Linear normal plot (Aluminium oxide wheel)	54
4.10	Linear contour plot (Aluminium oxide wheel)	54
4.11	Surface conditions and metallurgical analysis of surface	56

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Steel is an alloy that consists mostly of iron and has carbon content between 0.2% and 2.1% by weight, depending on the grade. Carbon is the most common alloying material for steel, but various other alloying elements are used, such as manganese, chromium, vanadium, and tungsten. Carbon and other elements act as a hardening agent, preventing dislocations in the iron atom crystal lattice from sliding past one another. Varying the amount of alloying elements and the form of their presence in the steel (solute elements, precipitated phase) controls qualities such as the hardness, ductility, and tensile strength of the resulting steel. Steel with increased carbon content can be made harder and stronger than iron, but such steel is also less ductile than iron. Today, steel is one of the most common materials in the world, with more than 1.3 billion tons produced annually. It is a major component in buildings, infrastructure, tools, ships, automobiles, machines, appliances, and weapons.

Surface grinding processes are industrial processes in which removal of unwanted material to get good quality of surface finish. It is one of the most important and widely used manufacturing processes in engineering industries. In the study of surface grinding process, the output quality is rather important. A significant improvement in output quality may be obtained by optimizing the cutting parameters. Optimization of parameters not only improves output quality, but also can reduce cost manufacturing. Grinding parameters include mode of dressing, table speed, depth of cut, cutting fluids and so on.

Nowadays, roughness plays a significant role in determining and evaluating the surface quality of a product as it affects the functional characteristic. The product quality depends very much on surface roughness. Decrease of surface roughness quality also leads to decrease of product quality. In field of manufacture, especially in engineering, the surface finish quality can be a considerable importance that can affects the functioning of a component, and possibly its cost.

Generally, the type of wheels plays a very important role, as it is responsible to obtain the quality of surface finish. This paper presents an experimental study of surface grinding with two type of wheel to investigate the relationship between abrasive tools with surface finish of workpiece in different table speed, depth of cut, and mode of dressing.

1.2 PROBLEM STATEMENT

The quality of surface finish is an important requirement for many grinded workpieces. Thus, the choice of optimized cutting parameters is very important for controlling the required surface quality. In grinding operation, there are many parameters such as table speed, depth of cut and dressing mode that have great impact on the surface finish. A smooth surface finish reduces the risk of system contamination, and increases the speed of cleaning and sterilization. All these while, there are numbers of studies are done to investigate the effects of table speed, mode of dressing and depth of cut on the surface roughness with two types of grinding wheel used which is silicon carbide and aluminum oxide. In this research, grinding operations will be carried out to generate the optimum surface finish by using table speed, dressing mode and depth of cut as parameters. The material that will be used is mild steel.

1.3 PROJECT OBJECTIVES

1) To investigate the influence of wheels types on surface finishing via experimental in term of surface roughness analysis.
2) Study the effect of cutting parameters on the surface quality of the machined surfaces.

1.4 SCOPE OF PROJECT

In order to achieve the objectives notified earlier, the following scopes have been identified:

1) Performed surface grinding operation. Grinding operation will be done on mild steel based on three machining parameters.
2) Determine the major grinding parameters that influence the surface finishing.
3) Investigate the surface roughness using the Perthometer machine.
4) Obtain optimal level of parameters for each performance using graph of S/N ratio.
5) Use the Analysis of variance (ANOVA) to get the relationship between the roughness and variables parameters machining.
6) Compared the data and decide which the most significant parameter that affect surface roughness by using Response surface method (RSM) modeling.

1.5 SUMMARY

Chapter 1 has been discussed briefly about project background, problem statement, objective and scope of the project on the effects of abrasive tools on surface finish when grinding mild steel with different parameters which is table speed, mode of dressing and depth of cut. This chapter is as a fundamental for the project and act as a guidelines for project research completion.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

From the early stage of the project, various literature studies have been done. Research journal, reference books, printed or online conference article were the main source in the project guides as they contain the current knowledge on particular research. The reference sources emphasize on effect of abrasive tools on surface finish when grinding mild steel. Then, the effects of abrasive tools on surface finish of mild steel will be justified using surface roughness value.

2.2 SURFACE GRINDING MACHINE

Grinding machines are used for finishing process. When greater accuracy than that obtainable on the milling machine or the lathe is required, recourse is had to grinding. This operation depends upon the abrasive or cutting qualities of emery, corundum, and carborundum. With workpiece properly held to a solid grinding wheel, it is not difficult to attain great accuracy. Surface grinding is used to produce a smooth finish on flat surfaces. It is a widely used abrasive machining process in which a spinning wheel covered in rough particles (grinding wheel) cuts chips of metallic or non metallic substance from a workpiece, making a face of it flat or smooth.

2.2.1 Process of Surface Grinding

Surface grinding is the most common of the grinding operations. It is a finishing process that uses a rotating abrasive wheel to smooth the flat surface of metallic or nonmetallic materials to give them a more refined look or to attain a desired surface for a functional purpose.

The surface grinder is composed of an abrasive wheel, a workholding device known as a chuck, and a reciprocating table. The chuck holds the material in place while it is being worked on. It can do this one of two ways: metallic pieces are held in place by a magnetic chuck, while nonmetallic pieces are vacuumed in place.

Factors to consider in surface grinding are the material of the grinding wheel and the material of the piece being worked on. The grinding wheel is not limited to just a cylindrical shape, but can have a myriad of options that are useful in transferring different designs to the object being worked on. When surface grinding an object, one must keep in mind that the shape of the wheel will be transferred to the material of the object like a mirror image.

2.2.2 Equipment

Figure 2.1: Surface Grinder with electromagnetic chuck, inset shows a Manual magnetic chuck

A surface grinder is a machine tool used to provide precision ground surfaces, either to a critical size or for the surface finish. The typical precision of a surface grinder depends on the type and usage, however +/- 0.002 mm (+/- 0.0001") should be achievable on most surface grinders.

The machine consists of a table that traverses both longitudinally and across the face of the wheel. The longitudinal feed is usually powered by hydraulics, as may the cross feed, however any mixture of hand, electrical or hydraulic may be used depending on the ultimate usage of the machine (i.e. : production, workshop, cost). The grinding wheel rotates in the spindle head and is also adjustable for height, by any of the methods described previously. Modern surface grinders are semi-automated, depth of cut and spark-out may be preset as to the number of passes and once setup the machining process requires very little operator intervention.

Depending on the workpiece material, the work is generally held by the use of a magnetic chuck. This may be either an electromagnetic chuck, or a manually operated, permanent magnet type chuck; both types are shown in the first image. The machine has provision for the application of coolant as well as the extraction of metal dust (metal and grinding particles).

2.2.3 Types of Surface Grinders

1) Horizontal-spindle (peripheral) surface grinders - The periphery (flat edge) of the wheel is in contact with the workpiece, producing the flat surface. Peripheral grinding is used in high-precision work on simple flat surfaces; tapers or angled surfaces; slots; flat surfaces next to shoulders; recessed surfaces; and profiles.
2) Vertical-spindle (wheel-face) grinders - The face of a wheel (cup, cylinder, disc, or segmental wheel) is used on the flat surface. Wheel-face grinding is often used for fast material removal, but some machines can accomplish high-precision work. The workpiece is held on a reciprocating table, which can be varied according to the task, or a rotary-table machine, with continuous or indexed rotation. Indexing allows loading or unloading one station while grinding operations are being performed on another.
3) Disc grinders and double-disc grinders - Disc grinding is similar to surface grinding, but with a larger contact area between disc and workpiece. Disc

grinders are available in both vertical and horizontal spindle types. Double disc grinders work both sides of a workpiece simultaneously. Disc grinders are capable of achieving especially fine tolerances.

2.2.4 Grinding Wheels for Surface Grinders

Aluminum oxide, silicon carbide, diamond, and cubic boron nitride (CBN) are four commonly used abrasive materials for the surface of the grinding wheels. Of these materials, aluminum oxide is the most common. Because of cost, diamond and CBN grinding wheels are generally made with a core of less expensive material surrounded by a layer of diamond or CBN. Diamond and CBN wheels are very hard and are capable of economically grinding materials, such as ceramics and carbides, which cannot be ground by aluminum oxide or silicon carbide wheels.

2.2.5 Lubrication

Lubricants are sometimes used to cool the workpiece and wheel, lubricate the interface, and remove swarf (chips). It must be applied directly to the cutting area to ensure that the fluid is not carried away by the grinding wheel. Common lubricants include water-soluble chemical fluids, water soluble oils, synthetic oils, and petroleum-based oils.

2.2.6 Grinding Machine Safety

Grinding machines are used daily in a industry process. To avoid injuries follow the safety precautions listed below.

1) Wear goggles for all grinding machine operations.
2) Check grinding wheels for cracks before mounting.
3) Never operate grinding wheels at speeds in excess of the recommended speed.
4) Never adjust the workpiece or work mounting devices when the machine is operating
5) Do not exceed recommended depth of cut for the grinding wheel or machine.

6) Remove workpiece from grinding wheel before turning machine off.
7) Use proper wheel guards on all grinding machines.
8) On bench grinders, adjust tool rest 1/16 to 1/8 inch from the wheel.

2.3 WHEEL STRUCTURE

A grinding wheel (more specifically, the rim, or the abrasive segments, of the grinding wheel) consists of abrasive grains (a.k.a. abrasive grits), bond material, and pores, as shown in Figure 2.2 (Jackson et. al., 2003). Grinding wheels can be manufactured in a variety of grades or structures determined by the relative volume percentage of abrasive grains, bond, and porosity (Bright and Wu, 2004). Grinding wheels and abrasive segments fall under the general category of 'bonded abrasive tools'. The properties and performance of bonded abrasive tools depend on the type of abrasive grain material, the size of the grit, the bond material, the properties of abrasive and bond, and the porosity (Z.J. Pei et al., 2006).

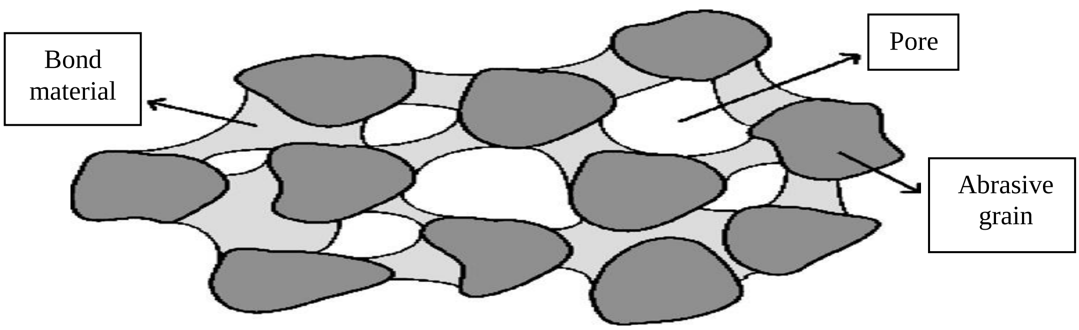

Figure 2.2: Compositions of a grinding wheel
(Z.J. Pei et al., 2006).

Figure 2.3 illustrates the open/closed structures of grinding wheels. When a great deal of abrasive grains are mixed with very strong bond material and pressed under high pressure, a dense, low porosity grinding wheel will produced. This closed-structure wheel is typically used for holding the form. When a small amount of grains are mixed with a small amount of bond material and pore inducers, a very open, highly porous structure grinding wheel will result once the pore inducers are removed. This open structure wheel is used to remove a great amount of materials from workpieces when chip clearance is a limiting factor (Salmon S.C., 1992). The wheel grade, frequently referred as the wheel hardness, indicates the resistance of the abrasive grains from breaking out of the wheel's bonding system. It indicates the bond strength - the holding power of the bond to hold the abrasive grains in position under grinding forces (Drozda and Wick, 1983). With hard wheels, relatively more fracture occurs within the grain than at the bond. With soft wheels, the wheels wear faster (C. Karpac et. al., 2004).

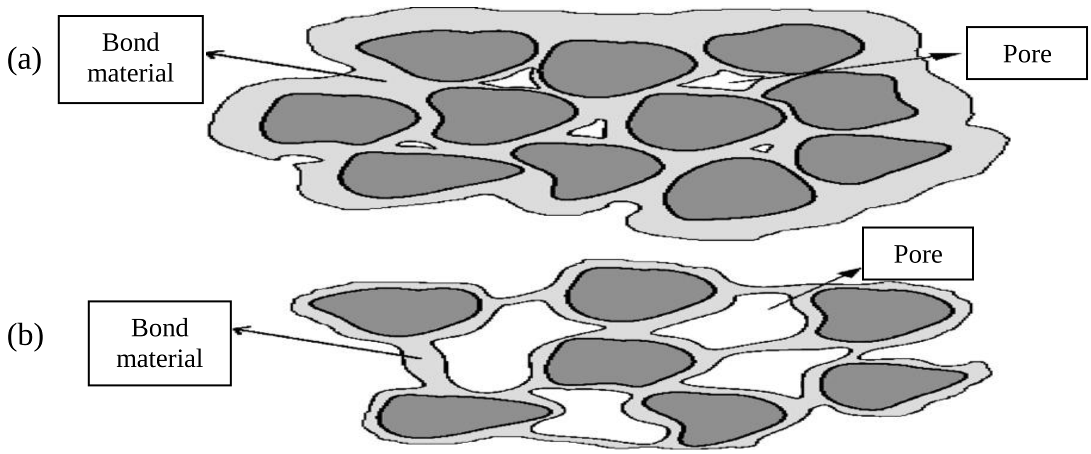

Figure 2.3: Illustration of wheels structure (a) Closed structure (b) Open structure (Z.J. Pei et al., 2006).

2.3.1 Grain Size

Grain size is determined mainly by the surface-finish requirement which the smaller the grain, the smoother the surface obtained. Conventionally, the grain size of abrasive particles is expressed in term of mesh sizes. The mesh size corresponds to the number of openings per linear inch in the wire gauze. Generally, small grain sizes can produce better finishes on ground surfaces, while larger grain sizes allow higher material removal rates. Furthermore, wheels with smaller grain sizes generally produce smoother surfaces. As the grain size becomes smaller, the roughness of the ground surfaces decreases (Z.J. Pei et al., 2006).

2.3.2 Bonds

The bond in a grinding wheel cements the abrasive grains together. Among other factors, the bond plays a predominant part in the diamond wheel performances and on the quality of grinding results. There are mainly three distinct wheel wear mechanisms, namely attritions wear, grain fracture, and bond fracture. Generally, the bond plays a very important role, as it is responsible for retaining the rigid inclusions against pull-out mechanisms (Malkin, 1989).

Surface finish performances and the obtained flow are linked with nature (Desmars and Margerand, 1994). In grinding, many differences in surface characteristics were underlined between the resin bond and the metallic bond. Resin is a soft bond that offers better quality of surface finish. However, wear of resin-bonded stones generally appears faster. This can decrease efficiency of the wheel as mentioned by Tong et al., (2006). To optimize wheel life and grinding performance, the bond wear rate should be equal to or slightly higher than the wear rate of the abrasive grain during grinding operations. The bond material must allow the diamond grains to fracture or pull out after they become worn to expose new cutting surfaces. It was found that ductile streaks at ground surface are found more when resin bond used than when metal bond is used (Venkatesh et al., 2005; Desmars and Margerand, 1994).

2.4 PARAMETERS THAT AFFECTING SURFACE FINISH IN SURFACE GRINDING OPERATION

2.4.1 Grinding Forces

As is well known, grinding force is one of the most important parameters in evaluating the whole process of grinding. Generally, the grinding force is resolved into three component forces, namely, normal grinding force F_n, tangential grinding force F_t and a component force acting along the direction of longitudinal feed which is usually neglected because of its insignificance. The normal grinding force F_n has an influence upon the surface deformation and roughness of the workpiece, while the tangential grinding force F_t mainly affects the power consumption and service life of the grinding wheel.

The force plays an important role in grinding process since it is an important quantitative indicator to characterize the mode of material removal (the specific grinding energy and the surface damage are strongly dependent on the grinding force) (Agarwal and Rao, 2007).

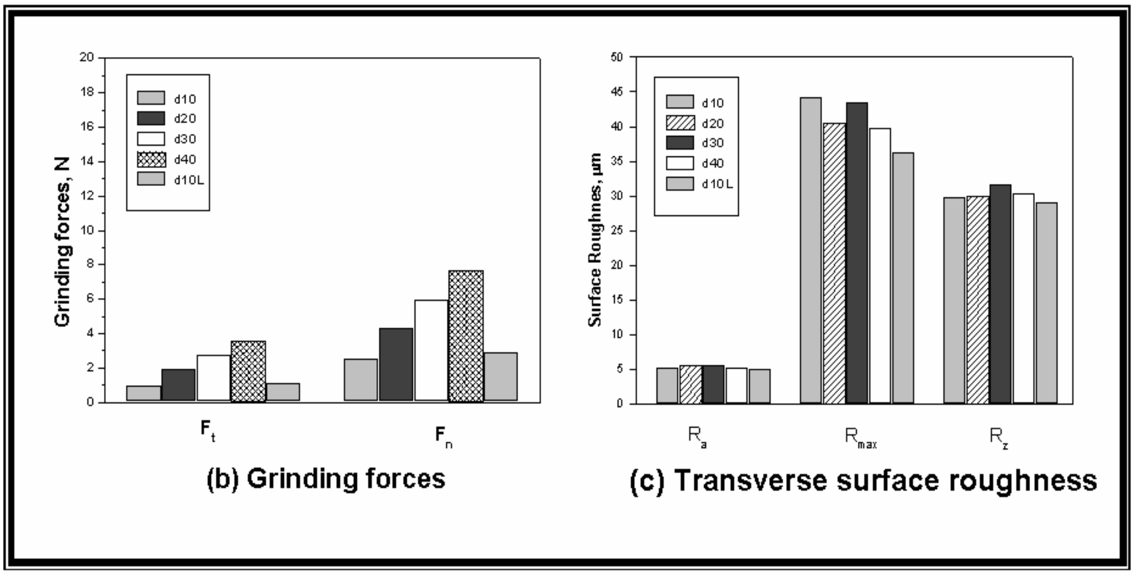

Figure 2.4: Grinding force versus Depth of Cut Graph
(Agarwal and Rao, 2007).

Grinding parameters like grinding velocity, traverse speed or wheel depth of cut affects the grinding force which in turn can cause fracture, rounding or flattening on few overlying grits thus, bringing more number of underlying grits into action. This change in topographical feature of single layer wheel, in various levels, affects the surface roughness of the workpiece. Grinding force increases with decrease in grinding velocity while the same increases with increase in table speed and depth of cut. Accordingly a trend is observed on decrease of surface roughness with decrease in grinding velocity and increase of both traverse speed and wheel depth of cut.

2.4.2 Dressing Mode

The surface profile of the wheel formed by dressing is determined by the relative motion between the diamond and the wheel, the characteristics of the wheel and the shape of the diamond. In early research, the dressing process was described as a wheel cutting process. Pahlitzsch and Brunswick (1954), suggested that the diamond cuts through the abrasive grains to produce cutting points. The dressing tool moves across the wheel surface with a dressing lead per wheel revolution while removing a dressing depth. Generally a fine dressing operation refers to the combination of a small dressing lead and a small dressing depth. Conversely, the combination of a large dressing lead and a large dressing depth is described as a coarse dressing operation. When the wheel is used for grinding, a pattern based on the distribution of abrasive grains transfers to the workpiece surface. This "grain cutting" theory has been assumed by many researchers since the surface profile of the ground workpiece can often be directly attributed to the dressing process. For a dressing diamond with a tip angle ¢, the theoretical peak-to-valley height of the thread profile generated on the wheel can be written as

$$Rp_{\mathrm{v}} = \frac{fd}{2tan\,(\frac{\emptyset}{2})} \tag{2.1}$$

According to this equation, the dressing traverse rate and the shape of the single-point diamond are particularly important. Bhateja et al. (1972), recorded wheel and workpiece profiles by stylus measurement. Dressing features clearly appeared on the workpiece surface, but could not be detected on the surface of the wheel. It was suggested that this was probably because any grooves produced in the wheel by the dressing process were very small compared to the roughness of the wheel.

2.4.3 Cutting Fluid

In general, the functions of the fluid include: mechanical lubrication of the abrasive contacts, chemo-physical lubrication of the abrasive contacts, cooling in the